ELECTRICITY;

ITS NATURE AND FORMS,

WITH A STUDY ON

ELECTRO-THERAPEUTICS.

BY

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PREFECE.

WHY a second edition? Before trying to answer this I will answer another question, viz.: Why a first edition? Over forty years ago, whilst a student at school, electricity had a peculiar charm for me. The chemistry, then in use, gave a good description, illustrated by plates, of the machinery in use, and as a text-book was all that was necessary to teach the elementary part of this subject. In particular it illustrated electrical induction. Later, when a student of medicine, I learned what was then known of the electro-magnetic machine, and of the magneto-electric machine. These machines gave only the induced current. At this time I only learned that there was an induced current in use; this is what is now called "the secondary induced current." Of this information I was quite proud and rather set myself up as a critic or a teacher. Some years ago an artisan, near my office, made a machine for winding silk or cotton around a wire for the purpose of insulating it and in order to show how well this work was done he made from this wire so insulated the necessary coils for an electro-magnetic machine.

This he kept to recommend his insulated wire. One day he took the electro-magnetic machine to a physician, a near neighbor of mine, for some explanation of its working. Whilst thus engaged I entered the office and seeing what was wanted volunteered the required information. When I got through with this, the doctor, either from malice or from desiring information, turned to his machine (which was a No. 4 Galvano-Faradic machine) and asked me to explain the two currents which it was claimed that the machine would give. "Here is a primary and also a secondary current, wherein consists the difference?" I took it up and looked at it and said nothing. The doctor kindly took it in pieces, and handed me the coils, showing me the connection, saying, "here the wires of the primary current go directly to the battery." I looked wise and replied that the primary was of course the battery current. "Well," said he, "how does it get off from the wire?" I had sense enough to reply, "I don't know." But when I got away I said to myself, I will know. I then commenced what proved to be a long study which involved a careful review of all the works on electricity at my command. Still the *why* of this primary or extra current eluded me. Whilst thus engaged a local

society asked me to prepare an essay for its next meeting, three months hence. Electricity being uppermost in my mind, I chose it for my subject. At the end of two months I was no nearer the *why* than at the start. One day I was at the telegraph office talking with the superintendent, who, in the course of the conversation, remarked that at the principal offices there was in use a machine called quadruplex with which two messages could be sent over the same wire at the same time. This involved the attendance of four instead of two operators—two at either end of the wire. These two messages could be sent in the same or in different directions; in other words, two currents of electricity could be made to pass over the same wire without interfering with each other. Here was a revelation. Perhaps there were two currents passing over the primary wire and one could be taken off and made to pass through the poles held by the patient, whilst the other went through the battery. This proved to be the fact although these currents did not pass over the wire at the same moment; *the battery current passed only through the battery but this passage induced another current on the same wire which passed, not through the battery, but through the electrodes held by the patient.*

My reward was when, at the end of the reading of the essay, an earnest listener remarked, "That is the first intelligent idea which I have ever had as to the working of this machine."

At this meeting, the request was made that I continue the subject and give at the next meeting more of the physiological effects of this powerful agent. As a fulfilment of this request the second essay was prepared and read. Now the answer to the first question, why a second edition? So many asked for the loan of the essay that I found it less trouble to me to have two hundred and fifty copies printed for distribution than to lend the MSS. These two hundred and fifty being exhausted the publisher thinks best to issue a second edition.

C. W. Boyce.

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ELECTRICITY.

ITS NATURE.

This term is applied to an all-pervading influence which has been studied and investigated, carefully, for many years by learned men and philosophers, and as yet we are not certain that we know anything more of its real nature than was known earlier in the investigation.

Three theories have been propounded as to its nature, each of which seems to have about an equal number of adherents.

The first we shall consider is called the two-fluid theory. It claims that there are two electricities, a positive and a negative, and that these two are in a state of equilibrium, or that there is just as much of one as of the other when in its normal condition, and when so, there are no manifestations. When there is any manifestation of electricity this equilibrium is disturbed, and there is a superabundance of either the positive or negative kind. That one

kind always attracts the other and repels like electricity. The effort of each is to attract just enough of the other to keep up the equilibrium. That electricity of high tension travels great distances to become thus neutralized. It is claimed that in the galvanic circuit both electricities travel on the same conductor in different directions and are thus neutralized: that this neutralization takes place equally on the whole circuit, since no neutral point has ever been found. As absolute proof of the truth of there being two electricities, it is claimed that the Leyden jar, or a battery of Leyden jars, has been so highly charged that not only the positive but also the negative discharge has pierced a plate of glass, and that, on inspection, the perforation made by the passage of either electricity shows plainly the direction the electricity took.

Probably the first idea of electricity came from a discovery made by Thales, of Miletus, (an Ionian philosopher,) that if a piece of amber was rubbed in a dry atmosphere it acquired the property of attracting light bodies, such as small pieces of paper or pith-balls. Later it was found that glass possessed this same property, but on comparing these attractions it was found that a light body which had been attracted by the amber was then repelled

by it, and afterward it was in turn more powerfully attracted by glass which had been rubbed. After having been in contact with the glass for a short time the light body was again attracted by the amber. These alternate attractions and repulsions continued until, as was afterward claimed, an equilibrium was obtained between the electricities of the amber and the glass. According to the two-fluid theory, the amber possessed negative and the glass positive electricities.

Althaus indicates that natural electricity is something more than a simple mixture of positive and negative electricities, and says, "we suppose these fluids to consist of an infinite number of smallest particles or molecules, each of which possesses attractive and repulsive powers, the molecules of one attracting those of the other, whilst molecules of the same fluid repel each other. While bodies are at rest, these fluids exist in such proportion that, although they do not destroy each other, their effect is counterbalanced; since at the same distance the attractive power of one of the fluids is equal to the repulsive power of the other. Natural electricity must therefore be *decomposed* in order that an action may be perceptible." In regard to the two-fluid theory, although he accepts it, he says,

"This theory of the electric fluid is not to be considered final, but only provisional. Indications are not wanting that it may at some future time have to undergo considerable modification, yet it enables us to classify our facts, and is more in accordance with the present state of our knowledge than any other view."

The second theory (Dr. Franklin's) claims that there is but one electricity, and that what are considered positive and negative are simply a plus and a minus condition; that is, when a body is positively charged it contains more electricity than belongs to it naturally, and when negative it contains less. Two bodies which are positive repel each other because they have too much electricity already, and two bodies one of which has too much and the other too little electricity, attract each other because they can, when together, give and take and thus become equalized. In the galvanic battery there is a constant current of electricity going from the zinc to the copper in the liquid, and from the copper to the zinc out of the liquid. The one-fluid theory claims that a light body is attracted by the amber because it has too little electricity, and that as they come together some portion of electricity passes to the amber. The light body

having given up some of its electricity is attracted by the glass from which it receives a portion of electricity, and this it carries over to the amber. The light body is simply a carrier to equalize the electricity between the amber and the glass.

Of these two theories this last seems to me to be the most simple, and so far as the literature of electricity is concerned it assumes that this is correct. All the terms used comply with it, and whatever theory, the description is of the current passing from the positive to the negative.

The third theory is that electricity is a force correlative with the other great forces of Nature, viz., light and heat; that its manifestations are by vibrations, or a change in the molecules of matter. As an illustration we may imagine a tube of equal calibre containing an indefinite number of balls of equal size and these nearly equal to the calibre of the tube, so that no friction need be caused when the balls are turned one way or another. Let us assume that this tube is perpendicular, when, as will be seen, the only friction will be between the balls themselves. If now the lowermost ball be turned in the least all the other balls must turn at the same instant and just the same distance, and this should the balls reach to infinity.

The advocates of this theory have framed no form of language to represent its workings but adopt the terms used by others who adopt the fluid theories. All suppose that there is a universal ether in which is manifested the phenomena of electricity. "Sir James Murray, M.D., who adopts Dr. Franklin's theory of electricity, publishes a series of extensive investigations and experiments made by himself, or under his auspices, some years since, from which we make the following extract: 'Electricity can produce thousands of effects; it is light, heat, galvanism, magnetism, and chemical action, or it is convertible into them. Its modifications constitute, in my opinion, that universal *ether film* which encircles all particles of matter and preserves by its powers of attraction and repulsion, the ultimate molecules of all organized beings in their natural relative connection and condition.'" —(Garratt.)

Beard and Rockwell, who adopt the third theory, use the following language, viz.: "All modern research tends toward the conclusion that the different forms of electricity, which are variously distinguished as *magnetism*, *Franklinism*, *galvanism*, *electro-magnetism*, are but expressions of one force, which force is, as we have seen, but a mode of

motion of the universal ether." (page 27.) "Electricity is a disturbance propagated in the molecules of a body and at the same time in the *ether*, pervading that body." (page 33.)

M. De la Rive says, "We may for the present say it is very probable that electricity instead of consisting of one or of two special fluids, *sui genesis*, is nothing more than the result of a particular modification in the state of bodies, which modification probably depends on the mutual action exercised on each other by the ponderable particles of matter and the subtle fluid that surrounds them on every side."—(Garratt.)

When we realize, if we ever do, how swiftly the electric influence travels or is exerted, we cannot comprehend that anything, either fluid or solid, can by any possibility pass through space at the rate of 288,000 miles in a second of time—about ten times around the earth.

"The velocity with which electricity is propagated is greater than that of any other agent with which we are acquainted, light not excepted; for while light moves at the rate of 192,000 miles in a second, electricity travels, according to Professor Wheatstone, over a distance of 288,000 miles in a second. This velocity, which is sufficient to make

the circuit of the earth ten times in a second, is so great that any artificial motion that can be produced appears to be rest itself when compared with it. The light of the electric discharge lasts, according to the same observer, hardly the millionth part of a second. If a wheel, which is made to revolve so rapidly that its spokes become invisible, be illuminated by a flash of electric light, all the spokes are for an instant seen perfectly distinct, as if it were in a state of rest. Insects on the wing appear fixed in the air; a cannon ball illuminated by a lightning flash seems to stand still, and an apparently continuous stream of water is seen as a succession of drops. The cause of these phenomena being that, however rapid the motion of bodies may be, the electric light has come and passed away before the motion has gone over a perceptible portion of space."—(Althaus.)

ITS FORMS.

It is generally understood that electricity is manifested in three different forms, viz., as magnetism, as static electricity, and as dynamic electricity.

Magnetism is that property which is manifested in the lodestone. This is a species of iron-ore

which has been rendered magnetic and retains this property permanently. It attracts soft iron and renders it magnetic so long as they are in contact. Steel is also rendered magnetic by contact with the lodestone, and it retains its magnetism permanently. This is a very broad practical difference: the soft iron becomes more powerfully magnetic than steel while the influence lasts, but it loses its magnetism as soon as contact is broken with the lodestone; the steel retains it.

If an insulated wire be coiled around a rod of steel or soft iron, and a current of galvanism be passed through or along this wire, the steel or soft iron within the coil takes on magnetism or becomes a magnet. This artificial magnet has the same power to impart the magnetic property that the lodestone has. The steel rod will retain its magnetism after the current of galvanism ceases to flow along the insulated wire, but the iron rod does not retain it.

Another property the rod has acquired, viz., a tendency, when free to move, to place itself in a position pointing north and south—the same end invariably pointing north, and the other south. If the coil of wire containing the rod of soft iron or steel be placed on a float in water, and the current

of galvanism be passed through the coil, the rod immediately, by its acquired magnetic power, begins to move the float so as to point toward the north and south, thus obeying the law of polarity.

The steel rod retains this property of polarity, and thus becomes of the greatest use, scientifically. It then becomes the magnetic needle.

There are three great sources whereby electricity is made manifest: by the effect of heat, by friction and by chemical action. Any body or substance (especially those which are composed of iron,) which is being heated at any given point, from which the heat radiates to the other parts of that body, manifests a current of electricity, and this current is from the heated to the cooler parts. This is a law of electricity. When the sun, that great source of heat, warms the earth, which in its revolutions presents constantly a new surface to the direct rays of that body, it follows from the law that there is a constant current of electricity flowing from east to west—from the heated to the cooler part. In its revolution the earth has not had time to cool toward the east, consequently the current is always toward the west.

On comparing this condition of the earth, with its constant current of electricity passing around it,

with the rod in the wire coil, where the galvanism is constantly passing around it, we cannot fail to recognize the similarity. The earth is rendered magnetic. The rod is rendered a magnet. All substances which have thus taken on the magnetic condition permanently, from the influence of the earth current, are called natural magnets.

It is found by experiment that any magnet when free to move at will, will always place itself at right angles to any current of electricity passing in its immediate vicinity. The constant current from east to west explains why the magnetic needle must place itself at right angles with this electric current.

From the above considerations we might reasonably infer, contrary to the general understanding, that magnetism, instead of being a form of electricity is only an effect. However, it is quite probable that magnetism is only one manifestation of electricity, since each, under proper conditions, as we shall see, induces the other.

These two conditions—the permanent and the temporary magnets—answer, in their own way, to fulfil two very important purposes. The one pointing with unvarying constancy to the north pole, guiding the mariner unerringly over the trackless ocean, and the other rendering it easy to telegraph

through all space where a conductor may be placed. The needle must be a permanent magnet. For telegraphing, no other form can take the place of the temporary magnet. The value of these magnets is entirely relative—the permanent magnet depends upon the fineness and the hardness of the steel for its strength, and the temporary magnet upon the softness and purity of the iron. The one should change as little as possible and the other as readily as possible. The firmer and harder the steel, the slower it takes on the magnetic state and retains it with the greater tenacity; the softer and purer the iron the more readily it takes on and gives up the magnetic condition.

By the use of the soft-iron magnet telegraphing is easy. It seems altogether probable that some other process would be invented whereby telegraphing could be done should the magnet disappear, but as yet this is only being experimented with, and no satisfactory result has been reached. As it is, telegraphing has become so simple an affair that any one who chooses can study its workings, and a description of the apparatus and its workings will convey most readily an idea of the temporary or electro-magnet. It requires that two places, separated from each other, shall be connected by a con-

ductor. A galvanic battery is necessary at one end of the conductor. Generally there is one at each end. These batteries must be connected with the earth, or a second wire must connect the batteries, in order to complete the circuit. At each place there must be an instrument to receive the message. The Morse instrument is the only one with which I am acquainted. This consists essentially of a piece of soft iron bent in the shape of an horse-shoe, around whose ends is coiled an insulated wire, so arranged that the battery current can be made to flow along it, and when the current thus flows through this wire the soft iron become a magnet, and so continues as long as the current continues to flow. In addition to the bent soft iron, there is a lever on which is a piece of soft iron so placed that it acts as an armature to the bent soft iron. The lever terminates in a point which is in close proximity to a moving strip of paper. In order to a clear understanding we will suppose that there is a battery at each end of the conductor. At each end also is an apparatus by which the operator can make or break the connection. This is called a key. When a message is to be sent the operator closes the circuit and a current of electricity flows along the conductor and around the bent soft iron,

thus rendering it magnetic. This being magnetic, attracts the armature and this brings down or up the lever which moves the point toward the moving paper, and by the point pressing in the paper a mark is made. When the operator opens the circuit the soft iron is demagnetized, and this allows the armature to withdraw and then no mark is made. It is thus in the power of the operator to make long or short marks, or even dots, at pleasure. A system of marks and dots correspond to the alphabet. The instantaneous making and unmaking of the magnet is a necessity. A permanent magnet has been used but it was found greatly inferior to the electro-magnet. This instrument was generally in use for many years, but lately it has been superceded, and now the sounds of the instrument are listened to and the message written out.

The electro-magnet is used in the construction of one class of machines for medical purposes, and gives them their names, viz., electro-magnetic machines. There are others constructed with permanent magnets and these are called magneto-electric machines.

"Magnetism produces two remarkable effects—sound and elongation. When a good ear is placed near an iron core, just as the current is being

established around it, a click is heard. The same sound is heard when the current is broken. Place a rod of soft iron in an electro-magnetic helix, with its ends resting in two trays, and musical sounds may be produced. Elongation of a bar, when magnetized, is thus explained. The bar may be supposed to be made up of particles united by cohesion but capable of removal.

"When the bar is magnetized these particles put their largest diameters lengthwise to the bar, or tend in that direction. That sound was an effect of magnetization was discoveaed by Page. The elongation of a bar by magnetization was discovered by Joule, of Manchester, one of the pioneers of the doctrines of the correlation and conservation of forces. Grove has also shown that iron filings, suspended in a cylinder, around which the current runs, attach themselves end to end."—(Beard and Rockwell, page 10.)

STATIC ELECTRICITY.

Static electricity is electricity at rest. This does not mean electrical equilibrium. It is in distinction to dynamic electricity which is in motion. Static electricity is an accumulation of electricity in or about bodies which are insulated. An insulated body is one from which electricity cannot escape.

To understand this, necessitates a knowledge of conductors and non-conductors. A conductor is any substance over or through which electricity can pass. Copper, silver, most of the metals, and water are good conductors. Copper wire, from its qualities as a conductor and its cheapness, is most commonly used. Glass is a non-conductor, and from its being so common and cheap is generally used as an insulator. Hard rubber is equally good and less destructible. Dry atmosphere is a non-conductor but moist air is not. Electricity can be collected upon any non-conducting substance, provided there is no conductor near enough to carry the electricity away. Such an accumulation is static electricity. When it is allowed to escape it becomes dynamic. Static electricity has its type in that of the machine and of the cloud. The electricity-charged cloud may be driven about by the wind, or be attracted by another cloud which has less or more electricity, and be in motion through space, yet if the electricity does not pass from the cloud to which it is attached it remains static. Let this cloud come near enough to any other cloud which is in a different electrical condition or near enough to the earth if differently electrified, and the electricity of the cloud will be discharged. Whilst the electricity is being dis-

charged it is dynamic. Static is often called frictional electricity, because friction, under favorable circumstances, always produces it. The electricity of the cloud is often the result of the friction to which it is subjected when driven through the atmosphere against different currents and against the higher portions of the earth, by the wind. (The greatest source of atmospheric electricity is undoubtedly evaporation. Each particle of vapor is charged with positive electricity.) Static electricity is not necessarily frictional. It may accumulate at the poles of a galvanic battery when the circuit is open.

Electricity does not pervade the substance of those bodies which manifest electrical conditions. It is on the surface. The substance may show a negative condition. Systematic and prolonged observation have shown that the earth is predominately negative in relation to the atmosphere about it, and the further from the earth these observations have been taken, the greater the degree of positive electricity has been found. The atmosphere is a great reservoir of electricity, varying from time to time at the earth's surface, where at times the electric condition is decidedly positive, and at others it is decidedly negative. Quite

recently Professor Loomis has been experimenting with this atmospheric electricity in telegraphing. He has been able with its aid to send messages to stations fifteen miles distant without connecting wires. This extract has just come to hand and I append it:

"There is really no end to the wonders of telegraphy. While the telephone is astonishing us, we learn that scientists are actually telegraphing through the air without the aid of wires. Professor Loomis flies a kite, using a copper wire instead of a kite string, and at a distance of ten miles he causes another kite to be raised in the same way, and he finds himself able to transmit signal between these kites. Since the days when Franklin flew his scientific kite, we have heard of nothing more wonderful."

The varying conditions of the atmospheric electricity at the surface of the earth from positive to negative and from negative to positive, are marked by different effects, both general and physiological. The interest to us is principally with the latter. Ordinarily these changes follow each other so closely that no continued physiological state is noted, but when one condition, either positive or negative, continues, as it often does, for days or even weeks, we

observe effects in proportion to this continuance. In a general way with a positive state of the atmosphere, if long continued, what diseases prevail are predominately sthenic, but usually the postive state is a healthy one. During a negative condition, neuralgias and allied diseases prevail. Under this state of the atmosphere diseases are prone to linger, and we administer our remedies almost in vain. Day after day as these conditions continue we wait and hope. One day follows another and no change for the better. By and by there comes on a change, the mercury falls, the winds arise and a storm ensues; the next day when we visit our patients there is a marked change for the better, we find that we are indeed in a different atmosphere as soon as we enter the house. The faces of the attendants are more pleasant and even smiling. The patients look more hopeful. Many cases yield and convalesce rapidly, and we are apt to credit to the last remedy given, what ought to be credited to the electric change and to the storm. This has been my experience for more than thirty years.

After the conclusion of the reading of this paper a friend called my attention to a series of articles in the thirteenth volume of *Harper's Monthly*, entitled "The Great Epidemics," in which occurs the

following paragraph, and being so appropriate to our present subject that I append it:

"Still the pestilence raged with unabated violence. The stagnant air teemed with deadly vapors. Scarcely a breeze ruffled the unbroken calm. The light of the sun, shining steadily in the sky, became hateful to those who were sickening under its beams. In vain they looked up to the unmerciful heavens for the shadow of a cloud. The blue arch bent over them, hot and stifling, like the dome of a furnace. Anxiously did they look for the change of the moon, in the hope of an alteration in the state of the atmosphere: but no change came, no breeze blew, no rain fell. Occasionally a haze would overspread the sky, light clouds would form, and supplicating eyes would gaze upon the mocking promise only to see it fade away into the general vapor that had no healing in its misty wings. So the hot September wore away and October, usually so balmy, arrived, but only brought increased mortality.

"The springs and wells began to fail, pastures were burned up, the dust extended two feet below the surface of the soil. To add to the universal distress, medical aid began to fail the people. Some of the physicians had fled, many were dead, more

were sick, and all were worn down with extreme fatigue. In one day it was estimated that six thousand persons lay burning with fever, and that only three medical men were able to be out of their houses. The stoutest hearts now began to fail and despair reigned supreme over the city, (Philadelphia). At this moment, as if to verify the adage, 'Man's extremity is God's opportunity,' a change took place. Dark clouds gathered over the sky, and on the 15th of October the long-desired, the prayed-for, the benevolent rain came pouring upon the parching city. The pestilence had received its death blow. The number of the sick immediately diminished, and by the 9th of November the plague was over."—(*Harper's Monthly*, vol. xiii., p. 789. Yellow fever.)

Our principle source of static electricity is the electrical machine. Commonly this machine consists of a cylindrical plate of glass, which can be made to revolve on its axis. A rubber of silk presses upon this plate whilst revolving. The friction between the glass and the silk develops the electricity in the glass, which is conveyed along what is called a prime-conductor and deposited upon any non-conductor in the near vicinity, or it may be discharged into the atmosphere. Any con-

siderable friction in a dry, heated atmosphere develops this electricity. High pressure steam also develops it in large quantities. In paper mills we have nearly all the requirements for making electricity manifest. Let me call attention at this point to a similarity between the effect produced on the substances used to produce frictional electricity, and the effect upon the metals used in a battery where galvanism is made manifest. In the battery one metal is more acted upon than the other, and the greater this difference between the metals in this respect the greater the amount of galvanism produced, and the one *least acted* upon collects the positive or is the collecting plate.

"It was observed by Callomb that the general deductions in regard to frictional electricity are that when two bodies are rubbed together the one whose particles are *least disturbed* is most disposed to collect positive electricity."

With the electrical machine, in dry, warm air, electricity may be made manifest at pleasure, and by means of the Leyden jar it may be collected and retained temporarily for use. *Temporarily*, since the air is not a perfect non-conductor and gradually the electricity escapes. The Leyden jar may be any glass jar which has been coated with tinfoil extern-

ally and internally to within two or three inches of the top. A varnished cover secures the open mouth of the jar. Through this cover passes a metal rod which is in connection with the inner coat of tinfoil. The rod terminates externally in a knob. When this knob is in contact with the prime-conductor of the machine, a few turns of the plate will fill or charge the jar with positive electricity. This electricity has great tension. Tension is a property whereby electricity leaps longer or shorter distances in order to reach objects in a negative condition, where it may be neutralized, and this is the reason why it can never be collected in any great quantity. In certain conditions of the atmosphere there is such a minus condition that very little or no electricity can be produced by the machine, and during the continuance of such a condition serious diseases have often prevailed. During several weeks in Paris where observations were made, some years ago, when there was an epidemic of cholera, no electricity could be produced. At last the machine gave a few sparks, and the next morning's bulletin annouced a decrease in the number of cases of cholera. The decrease of the disease kept pace with the increased manifestations of electicity on the machine.

At this stage of the reading the question was asked, "Does the presence and absence of positive electricity account for epidemics?" I here present an extract from Dr. Garratt's Medical Electricity, page 75: "We know that Andreaud made daily observations and experiments in and about Paris during the cholera there, which show a striking coincidence between the amount of electricity and the virulence of the epidemic. In a letter to the president of the French academy, he says:

'The machine I have used for my daily observations is rather powerful. In ordinary weather it gives, after two or three turns of the wheel, brilliant sparks of five or six centimetres. I have noticed that since the invasion of the epidemic I have not been able to produce on any one occasion the same effect. During the months of April and May the sparks, obtained with great trouble, have never exceeded two or three centimetres, and their variations accorded very nearly with the statistic variations of the cholera. This was already for me a strong presumption that I was on track of the important fact I was endeavoring to find. Nevertheless I was not yet convinced, because we might attribute the fact to the moisture of the air, or to the irregularities of the electric machine. Thus I waited with im-

patience the arrival of fine weather with heat, to continue my observations with more certainty. At last fine weather came and, to my astonishment, the machine though often consulted, was far from showing as it ought, an augmentation of electricity, but gave signs less and less sensible to such a degree, that during the days of the 4th, 5th, and 6th of June, it was impossible to obtain anything but slight cracklings without sparks. On the 7th the machine remained quite dumb. This new decrease of the electric fluid had perfectly accorded, as is too well known, with the renewed action of the cholera; for my part, I was not more alarmed than astonished; my conviction was complete. I saw only the consequence of the fact already supposed. It may be imagined with what anxiety, in the moments of the crisis, I consulted the machine, the sad and faithful interpreter of a great calamity. At last, on the morning of the 8th, some feeble sparks reappeared, and from hour to hour electric intensity increased. I felt with joy that the vivifying fluid was returning in the atmosphere. Toward evening a storm announced at Paris that the electricity had re-entered its domain; to my eyes it was the cholera disappearing with the cause that produced it. The next day, (Sunday, the 9th,) I continued my observ-

ations; the machine then, at the least touch, rendered with facility most lively sparks. Now, it is stated that in the six days following the 8th of June, the mortality in Paris fell regularly from 667 to 335.'"

As long as this electricity remains in the Leyden jar it is static, whether we carry it about or leave it stationary, but the instant we touch the knob with a conductor, which is in connection with the external tinfoil, or with the earth, a discharge takes place and it becomes dynamic. Owing principally to the difficulty in managing this form of electricity, it is less used than the other forms, which are more under control. Yet in many cases it is used with undoubted benefit.

DYNAMIC ELECTRICITY.

Dynamic electricity is, particularly, electricity in motion. Its type is that which results from chemical action. The induced current is also of this variety. Electricity from chemical action is as universal as chemical action itself. No chemical action ever takes place without electricity being set free. It is with this electricity that we have to do, principally, in physiology, in medicine, in science and in art.

Physiologically, the everywhere-present vitality

and the everywhere-present electricity: so universal that they have been thought to be one and the same. The innermost processes of nutrition presided over by vitality are always accompanied by manifestations of electricity, and here, where the effete matter is thrown off and replaced by new, is the everywhere-present chemical action—carbonic acid formed and removed, nutritious atoms and oxygen taking its place. No thought nor muscular action, no secretion nor assimilation but is presided over by vitality accompanied by chemical action and manifestation of electricity. No atom of the animal system but is undergoing constant change accompanied by electrical phenomena. Whilst vitality remains, organic chemistry presides and preserves; when vitality departs, inorganic chemistry destroys.

The galvanic battery is the principal source of dynamic electricity, and with the construction and workings of this apparatus we must be familiar in order to use electricity with pleasure to ourselves and profit to our patients. In order to this understanding it is necessary for us to begin at the beginning. Not at the discovery of galvanism, but where it began to be understood that although chemical action always developed a current, this

current was liable to be interrupted and so interfered with that it became unreliable and finally ceased to flow.

Volta's pile when first set in action, gives a good current of electricity, but begins to diminish from the first, and gradually ceases to work. The construction of this pile is a series of zinc and copper plates, and pieces of cloth of nearly the same size as the plates. First, a zinc plate; second, a piece of cloth, and this saturated with acidulated water; third, a copper plate; again another series of zinc, cloth and copper, and so on *ad libitum*. The terminal plates are connected by a copper wire. The chemical action in this apparatus is, that the acidulated water attacks the zinc and a combination takes place between the acid and the zinc, forming a salt of zinc. The water is decomposed and its component parts separate and go in different directions. The oxygen goes to the zinc, and the hydrogen to the copper. The result of this is that after the plates become covered by these gases there commences another current, generated by the oxygen and hydrogen, which flows in a contrary direction to the zinc-copper current, and as it accumulates in strength finally overcomes the original current and the apparatus ceases to work.

We select as the next step in our investigations a description of a simple battery, composed of two metals and one liquid: one which has been and still is used to a considerable extent. One of these metals must be more easily acted upon, chemically, than the other: and those metals which are most unlike in this respect make the best battery. It is not imperative that there should be *two metals* to form a galvanic battery, for the galvanic current may be started whenever two substances holding the above relation to each other are properly connected. The gases, oxygen and hydrogen, hold the proper relations to each other to form a battery, a description of which will be given in due time. Of the metals, zinc is used almost universally owing to its cheapness and its property of being easily acted upon chemically. Copper is the next metal in most common use, and is very little acted upon chemically. Silver, platinum, and gold, are better than copper, since they are more nearly indestructible, but owing to their cost they are not commonly used. Carbon is both indestructible and cheap, and is coming into use quite extensively.

The fundamental principle of a good battery is that one of the substances must be easily acted upon chemically, and the other as little as possible, the

greater the difference the greater the current of galvanism made manifest.

Let us now take as our illustration, the simple battery, composed of a zinc plate, a copper plate, and dilute sulphuric acid. As soon as the zinc and copper are immersed in the acid solution and a connection made between the metals outside of the solution, chemical action takes place between the acid-water and the zinc and a current of galvanism begins to flow, in the solution, from the zinc to the copper and out of the solution, through the conductor, from the copper back to the zinc, thus forming a *circuit*. This battery, when new, works well and gives a good current of galvanism, but soon begins to lose its activity and finally gives little or no current. For general and medical purposes it cannot be relied upon. If we examine the chemistry of this battery we may see why it so soon loses its power. It is quite important that we should understand this process, since it explains just where nearly all trouble arises in the use of galvanic electricity. The zinc and the sulphuric acid having a great affinity for each other, and being in immediate contact, they unite by the aid of the water and form a sulphate of zinc. In doing this, an atom of zinc first unites with an atom of oxygen, thus forming

an atom of oxide of zinc. This atom of oxide of zinc then unites with an atom of sulphuric acid and forms an atom of sulphate of zinc. This salt remains in solution. The atom of oxygen which unites with the zinc is obtained by the decomposition of an atom of water which is in immediate juxtaposition with the zinc plate in the solution. This sets free an atom of hydrogen. This action is constantly going on. Sulphate of zinc being formed and remaining in solution, and hydrogen being set free. A part of the hydrogen thus set free rises immediately to the air and is diffused therein. A part, however, is not thus disposed of, and it is with this part that we are now interested. There is a decomposition of not only that atom of water which is in contact with the zinc plate, *but of all the atoms of water between the zinc and copper plates, and immediately a recomposition of new atoms of water*, so that the atom of hydrogen set free at the zinc plate unites with the atom of oxygen of its nearest neighbor atom of water thus forming a new atom of water, and this atom of hydrogen thus set free takes the oxygen of its nearest neighbor atom of water, and so on until the copper plate is reached each atom of oxygen moving at each change one step toward the copper. Thus there is a constant

supply of oxygen arriving at the zinc plate, and a constant supply of hydrogen arriving at the copper plate. This hydrogen adheres to the copper and soon, unless dispersed, entirely covers the surface of the copper. When this point is reached, the copper is separated from the liquid by a layer of hydrogen, and this layer of hydrogen does not allow the galvanic current to pass, but interrupts its passage. This is called polarization of the plates. To avoid this polarization is what we wish in the construction of the battery. (In Smee's battery, silver, on which has been precipitated finely-divided particles of platinum, is substituted for the copper, and this has been found to work well: the hydrogen not being able to adhere to the rough platinized-silver, but rises to be dissipated in the air.)

In the zinc-copper battery, above described, any process which will dislodge the hydrogen restores the conditions necessary to a battery. Stirring the liquid washes off the hydrogen. Lifting the copper plates out of the liquid also dissipates it. This, however, requires too much attention, consequently other batteries have been invented which prevent the accumulation of hydrogen on the copper plate, one of which does its work so well that, so far as I am informed, it is being used quite generally in

telegraphing and also in medical electricity. This is a modification of Daniels' battery, and is called the gravity battery. In this battery the copper plate is immersed in a saturated solution of sulphate of copper, which is placed at the bottom of an appropriate jar. The zinc plate is suspended above the sulphate of copper solution in dilute sulphuric acid. The sulphate of copper solution being heavier than the dilute sulphuric acid retains its position in contact with the copper plate, whilst the sulphuric acid solution being lighter remains in contact with the zinc. A surplus of sulphate of copper is necessary in order that it may be dissolved as fast as decomposition takes place by the chemical action, so as to keep the liquid about the copper plate in a state of saturation.

The chemistry of this battery is, that as the dilute sulphuric acid acts upon the zinc forming sulphate of zinc, the liberated hydrogen, which does not immediately escape, travels by electrolysis toward the copper plates, where, instead of adhering to the copper, it decomposes an atom of the sulphate of copper solution, precipitating the metallic copper upon the copper plate, thus increasing its bulk, and then uniting with the atom of oxygen set free, forming an atom of water. The sulphuric acid set

free remains in the solution replacing to some extent the acid used up in forming sulphate of zinc.

Two things are necessary in order to keep this battery in constant action, viz., to add from time to time sulphate of copper as this salt is used up, and to add what water is lost by evaporation. Practically this battery is found to act constantly for a long time if proper care is used not to stir the liquid so as to bring the sulphate of copper solution in contact with the zinc. This accident soon destroys the action of the battery, in this way: when the zinc is in contact with a sulphate of copper solution the hydrogen set free on its surface immediately decomposes an atom of sulphate of copper solution, precipitating the copper on the zinc plate in the form of an oxide, which soon covers the zinc and destroys the conditions necessary to a battery, by opposing copper to copper. Those of us who formerly used the electro-magnetic machine, where the battery was composed of a copper cup containing sulphate of copper solution in which was suspended the zinc plate, will remember how difficult it was to keep the zinc clean. We were obliged to scrape off the oxide of copper with a knife almost every time the machine was used. With perfectly pure zinc this deposit is slight, but it is difficult to

obtain perfectly pure zinc. Ordinary zinc contains some proportion of other metals, or other impurities, which, in the acid solution, form independent local currents (or independent local batteries), and these currents also cause the oxide of copper to be deposited. To some extent, amalgamating the zinc plates remedies this tendency, since the amalgamated zinc closely approximates to pure zinc for battery purposes. In the zinc-carbon batteries what hydrogen arrives at the carbon plates is absorbed by the carbon and does not interfere with the galvanic current, unless the carbon becomes completely saturated and the surplus separates the carbon from the liquid. In this case immersing the carbon plates in boiling water removes the hydrogen and restores its efficacy. The substances used in the solution in these batteries unite chemically with the liberated hydrogen and thus prevent almost entirely this deposit.

By the use of the gravity battery we have succeeded in obtaining a constant current of excellent quality and fair quantity, and we have got rid of the difficulty of the polarization of the plates only to encounter it out of the battery at the electrodes. A current of galvanism always produces electrolysis of any liquid through which it passes, whether in

or out of the battery. (The process of decomposition of the water above described, is called electrolysis.) If we place the poles of a galvanic battery, whilst in action, in water, the water completes the circuit and the current passes through the water. Bubbles of gas appear at either pole, oxygen at the positive and hydrogen at the negative pole. The same result follows when the current is passed through animal tissue. *All liquids* through which the current passes are decomposed and again immediately recomposed, the same as we have seen takes place in the battery whose chemistry has been above described, and if sufficiently prolonged sufficient polarization is produced at the electrodes (or poles) to arrest the galvanic current.

If we take a series of pairs of platinum plates and pieces of cloth and connect the terminals with the poles of a galvanic battery, in action, we may illustrate this polarization. Arrange the series so that we have first a platinum plate and next a piece of cloth wet with water, or acidulated water, and next another platinum plate: next another piece of wet cloth, and so on as far as we choose. If now we allow the current to flow through the series the water will be decomposed, the oxygen going to the positive pole and the hydrogen toward the negative.

Since these gases cannot permeate the platinum plates they will accumulate upon the opposite sides and we shall have between each pair of plates a deposit of oxygen and a deposit of hydrogen, separated by the wet cloth. Each deposit of oxygen and hydrogen, separated by the wet cloth, acts as independent electrodes and serves well to illustrate what takes place at the ordinary electrodes where a galvanic battery is in action. Always as soon as the circuit is closed by introducing any moist substance between the electrodes this moisture begins to be decomposed the same as the water in the battery, and the oxygen, step by step, atom by atom, moves toward the positive pole, whilst just as steadily does the hydrogen approach the negative. The result of this electrolysis is, that in time, as the gases accumulate, both the platinum plates, as well as the ordinary electrodes, will oppose a new current to the galvanic current and either diminish or interrupt it. Unpolarizable electrodes have been invented and when used are much pleasanter for the patient. They also prevent the accumulation of gases. I am not familiar enough with their construction to undertake their description.

These galvanic currents are called direct, since they flow directly from the batteries, in distinction

from the induced currents. They are also called continuous currents, because there is no interruption. The induced current is called the interrupted current, because it is only of momentary continuance, viz., at the instant of making and breaking the inducing current. This will next claim our attention.

INDUCED ELECTRICITY.

If we place any conductor, in whose circuit is a galvanometer, near another conductor through or along which a current of galvanism is made to pass, at the instant when the galvanic circuit is closed, the needle of the galvanometer will be deflected; also, when the circuit is opened. During the continuous flow of the current the needle will remain at rest, the same as when no current is passing. This deflection of the needle shows that at the commencement and at the cessation of the current in the one conductor there is a momentary current of electricity induced in the other conductor. We must understand distinctly that these induced currents are only of momentary duration and that during the continuous flow of the galvanic current there is no induced current. The momentary induced current taking place when the galvanic current commences to flow is in a direction *contrary* to

the inducing current and the induced current at the cessation of the galvanic current flows in a direction *the same* as the inducing current. Again, if a conductor which includes a galvanometer is in the vicinity of a piece of soft iron which is being magnetized and demagnetized, at the instant these changes in the soft iron take place the needle will be deflected, thus showing that momentary currents of electricity are being induced in the conductor. The currents induced at the changes in the soft iron are in different directions. A thorough knowledge and appreciation of these points are necessary in order to understand the electro-magnetic machines.

In medicine we now use the two currents, viz.. the galvanic current (which has been sufficiently described) and the induced current which we are now investigating. In the induction apparatus or the electro-magnetic machine there are several parts with which we should be thoroughly acquainted in order to clearly understand its workings. These are, first, the battery; second, the inner coil; third, the core of soft-iron wires, and fourth, the outer coil. This apparatus gives three distinct currents of electricity, viz., the battery current, the primary induced or extra current, and the secondary or ordinary induced current. The battery may be any

good constant-working element. This battery current simply works the machine, is the inducing current and only flows through the inner coil and around the electro-magnet which works the vibrator. This current *never* passes through the electrodes (or poles). The inner coil may be made independent of the soft-iron core, which can be introduced afterward, or it may be coiled around the core and remain permanently around it. This inner coil is formed of insulated wire of sufficient size that the galvanic current may pass along it without resistance. Its length depends upon one condition, viz., the longer the wire, in the inner coil, without offering serious resistance to the passage of the galvanic current, the greater will be its inducing power. Ordinarily this wire is from three to five or even ten yards in length. The ends of this wire terminate at the different metals of the battery. Some mechanism is introduced into the circuit of this wire in order to make and break the connection or to open and close the galvanic circuit, for on this depends the induced current. This wire must be completely insulated by winding it with thread or silk and then varnishing it.

The core, which may be either a soft-iron rod or a bundle of soft-iron wires, the latter of which is

best, is placed in the helix formed by the inner coil.

We now have enough of the apparatus to illustrate how the extra current is induced. In order to a clear understanding of this electro-magnetic machine let us use as an illustration what we see in the every-day business of telegraphy. In all the principal offices are instruments called quadruplex, whereby at least two currents of electricity are made to pass over the same wire, either in the same direction, or in contrary directions, or perhaps, putting it more correctly, we may say that two messages may be sent over the same wire at the same time without interfering with each other. Here, in your city (Syracuse), you may see at any time this phenomena by visiting the telegraph office. Whether at the intervening offices other instruments may be attached to this same wire and messages sent I am not informed, but this even need excite no astonishment. It is no more difficult to believe that several currents can be made to traverse the wire and carry intelligence than that two can. With a clear understanding of this fact, which any of you can verify, all difficulty in understanding the working of this machine vanishes. In action, two or more currents of electricity are always passing over the inner coil and they never interfere with

each other. When the connection is made with the battery, or the circuit is closed whereby the current is allowed to flow through or along the inner coil and back to the battery, and when this circuit is opened arresting the flow of the battery current according to the principles enumerated heretofore, we have two sources of induction. At the instant when the galvanic current starts, the soft-iron core being in the vicinity of a conductor through which a galvanic current is made to flow, becomes magnetized and this change in the soft-iron core induces a momentary current in the inner coil around it, but in a direction contrary to the current which induces the magnetism. Remember that this induced current is on the same wire on which the inducing current is flowing. At the same instant that the galvanic current starts in the inner coil each spiral of this coil being in the vicinity of each other spiral of this same coil has a momentary current of electricity induced in it by this proximity to each other, *for each spiral holds this relation that it is a conductor which is near another conductor through which a current of galvanism is flowing.* In this same manner each turning of each spiral induces a current in each neighbor turning for this same reason, and all these bits of induced currents flow in the same

direction, and that is contrary to the inducing current. The sum of these induced currents is infinitely greater than the current which is induced in a wire of the same length which is simply placed on a straight line parallel with another wire carrying a current of galvanism, for by experimenting with this straight wire it is found to give little or no shock, whilst the shock from the coil can hardly be endured.

We now have three distinct currents of electricity on this inner coil at the same instant, viz., the battery or inducing current, the magnetically-induced current, and the galvanically-induced current. Since at the time that these three currents are passing along the inner coil the circuit is closed these currents flow into and through the battery and but a small part, if any, passes through conductors connected with the electrodes. Beard and Rockwell estimate that copper conducts several thousand million times better than the human body, consequently whatever part of the electricity that would be diverted to the electrodes would be so very infinitesimal that in a close description of the workings of this apparatus we may safely say, that no perceptible effect is ever produced. Indeed, in this case, if any electricity passes through the electrodes it

would be a derived current. A derived current is one which is taken from a circuit and it follows fixed laws in its strength. We will suppose a current established through a conductor. If we now connect another conductor to the original one, which is of the same size and length as that put between the connections, the current will be divided equally between the old and the new route. If the new conductor is longer and smaller, the amount of electricity diverted is in equal inverse proportion to the increased length and smallness of the new conductor. If of twice the length and still of the same size, then the derived current will be one-half the strength of what is left on the original circuit, or one-third of the original current. In the electromagnetic machine according to the estimated conductivity of the copper compared with animal tissue, what electricity, if any, is diverted through a person holding the electrodes would be *several thousand million times less* than what would pass through the battery, allowing for the difference in size between the wires and the person's wrists through which the electricity passes.

Now when the galvanic circuit is opened according to the foregoing principles the soft-iron core is demagnetized, and this change induces a momentary

current in the coil surrounding it in a direction the same as the departed galvanic current. At the same instant a current is induced in each spiral of the coil by the cessation of the galvanic current in these spirals, and this current is also in the same direction as the departed galvanic current. We now have two induced currents on the same coil at the same time and in the same direction, or we may say two sources of induction for what becomes the same current. The connection with the battery being at this time broken these currents *cannot* pass through the battery, and in consequence, if there is any connection between the coil and some electrode these currents *must* pass along this connection. Such a provision is made by soldering two wires upon the coil-wire near its ends and these wires connect with electrodes which may be held in the hands or be applied to any part of the system, and thus whoever holds these electrodes receives through his system these two currents. These currents compose the "extra" or primary induced current.

Thus we have a one-way current which is more or less continuous as the connection is more or less rapidly made and broken. This current closely resembles the galvanic current. It produces electrolysis and heat, and decomposes compound sub-

stances. As a remedial agent when the galvanic current cannot be procured, we very often use this extra current to good purpose. We must not forget that the induced current is of only momentary duration and is made up of little bits of currents. The galvanic current, as long as the circuit is unbroken, flows constantly, and this constitutes the broad difference between it and the induced current.

The external coil is simply a much longer and finer insulated wire wound either immediately upon the inner coil or else upon a shield so as to be easily withdrawn, partly or wholly as circumstances may require. The longer and smaller this wire is, the greater the amount of induced electricity, provided that it is perfectly insulated. The least break in the insulation destroys its efficacy. The current in this coil is induced by the passage of the galvanic current in the inner coil, and has no connection with the battery. This current is not a one-way current but goes in a direction contrary to the inducing current when it starts, and in the same direction as the inducing current when it stops. This electricity closely resembles frictional electricity, being of great tension and small quantity. It cannot be used for electrolysis since whatever the one-way current decomposes the other one-way cur-

rent immediately recomposes, and thus there is no deposit at either electrode. As yet no apparatus has been invented whereby these two currents have been made to pass through a conductor in the same direction.

Althaus says, "It would therefore appear erroneous to speak of a permanent positive and negative pole in an induction apparatus for physiological or therapeutical purposes. Such is, indeed, the opinion of M. De la Rive, who explains the difference in the physiological and therapeutical action of the extra current and of the current induced in the second wire, partly by the circumstance that the extra current always moves in the same direction, whilst the current induced in the second wire alternately runs in contrary directions. But this author has evidently disregarded the fact that the current induced in the second wire has scarcely any effect at all on *closing* the circuit, while it has a powerful physiological action on *opening* the circuit. We may, therefore, when employing induction currents in physiology or therapeutics, only consider the current induced on opening the circuit which has a direction equal to that of the battery current." In comparing the different electricities Althaus says, "the chemical action of frictional electricity is very

feeble, since the quantity of matter decomposed is not proportionate to the tension, but to the quantity of electricity employed, and the quantity of frictional electricity is small. The Voltaic pile, on the other hand, yields a very large quantity of electricity, and therefore produces chemical decomposition with the greatest facility. Faraday has calculated that the great Leyden battery of the Royal Institution would require to be charged by 800,000 turns of a powerful plate-machine of fifty inches in diameter, to supply electricity sufficient to decompose a grain of water. If this charge of the battery were concentrated in a single spark, it would resemble a great flash of lightning; yet its quantity would only be equivalent to that which is produced in about five seconds by a single pair of Grove's battery. Faraday has also estimated that the quantity of electricity in action, during a severe thunder-storm would correspond to the quantity of electricity set free by the chemical action of one grain of water on four grains of zinc."

We see from the workings of the electro-magnetic machine that when an insulated wire is coiled around a rod of soft iron and a current of galvanism is passed through this wire the soft iron becomes a magnet, and, reciprocally, when this soft-

iron rod thus becomes a magnet and when it is demagnetized, currents of electricity are induced in the insulated wire surrounding it. The first is called electro-magnetism, and the second magneto-electricity. On this principle of magnetizing and demagnetizing a piece of soft iron is constructed the magneto-electric machines.

When a piece of soft iron is placed in contact with a magnet, it becomes magnetized. Absolute contact is not imperative to induce magnetism in the soft iron. Placing it in the immediate vicinity of a magnet renders the soft iron magnetic. If this piece of soft iron be wound with an insulated wire and then brought near a magnet, at the moment of approach there is induced a momentary current of electricity in this coil by the soft iron becoming magnetic, in a certain direction. As long as the soft iron remains in the near vicinity of the magnet it remains magnetic and no current is induced after the momentary one, but when the soft iron is removed it is demagnetized or loses its magnetism, and there is a momentary induced current in a contrary direction to the first. On this principle are constructed the magneto-electric machines used in medicine and in the arts. By using one or more horse-shoe magnets a magneto-electric machine

can be constructed which will give a current of induced electricity far superior to the electro-magnetic machine just described. A description of a machine with a single magnet will suffice to illustrate this principle :

A good horse-shoe magnet is fixed upon a substantial frame in such a position that the ends of a soft-iron rod, bent in the shape of a horse-shoe, may be made to revolve in the vicinity of the poles of the permanent magnet. This soft-iron rod must be so fixed that the ends shall be in close proximity to the poles of the magnet at one instant of its revolution and at another instant removed from the poles. An insulated wire must be wound around the ends of the soft-iron rod. At each revolution of the soft-iron rod, at the instant when each end of the rod approaches its respective pole of the magnet, the iron becomes magnetic and this change induces a current of electricity in the insulated wire in a certain direction, and when the arms have passed the poles of the magnet the soft iron is demagnetized and another momentary current of electricity is induced in the insulated wire, this time in an opposite direction. These currents are made to pass over a conductor in one direction and thus form a one-way current by connecting the ends of

the wire in such a way that at each revolution the point of contact with the conductor changes. With such a current everything may be done that can be with a continuous galvanic current. It is of high tension and of great quantity. Such a machine, constructed with several magnets and driven by steam, is in use at the prison at Auburn where electro-plating requires a steady one-way current. Any change in the direction of the current dissolves the plating as soon as it is deposited, and as a consequence there is no plating done. This machine at the prison will heat a wire almost at once to a white heat, which is from 1½ to 3 feet in length, and it will be consumed almost like a cotton string in the flames of a lamp. The effect of the electricity from this machine is simply immense and no animal tissue can bear it for an instant. The attendants are obliged to use the greatest care in order to avoid accidents.

One magneto-electric instrument yet claims our attention, viz., the telephone. This is constructed with a permanent magnet, an insulated copper wire and a thin piece of soft iron which acts as an armature to the magnet. It also acts as a drum. The insulated wire is coiled around one end of the magnet and the ends of this wire are continuous with

wires reaching to the station with which we wish to communicate, or one with the station and the other with the earth. The whole is enclosed in a hard-wood or hard-rubber case which acts as a resonantor. The soft-iron armature is placed at the end of the magnet and immediately across an opening in the case where the mouth is applied when speaking. At the other station is another instrument to receive the communication. In this instrument we have a new experience in induction. In the immediate vicinity of a magnet there is what is called a magnetic field which under ordinary circumstances is not manifest, and until a short time was not known to exist. When the field is disturbed it produces electric effects. In the telephone any wave of sound striking the drum causes a vibration and this disturbs the magnetic field. This disturbance induces a current of electricity in the insulated wire which is transmitted through the conductor to the other telephone. The current arriving at the other telephone produces a disturbance in its magnetic field which vibrates the armature and reproduces the sounds transmitted. We suppose that the armature vibrates exactly as the first armature does and thus reproduces the exact sounds. The tones of the human voice are transmitted so nearly as they were

uttered that anyone acquainted with the speaker can recognize the voice.

ELECTRO-PHYSIOLOGY.

A STUDY.

Electricity has two very prominent effects upon living animal tissues. First, a destructive effect upon both healthy and diseased tissue, and, second, a restorative effect upon deranged or diseased tissue. Its destructive effect is made use of by the surgeon in the removal of morbid growths by electrolysis and the galvano-cautery. Its restorative effect is made use of by the physician to a great extent, and perhaps principally, in strengthening and bringing back function when weakened or lost.

All moist substances through which electricity passes are decomposed by this passage and except near the electrodes are immediately recomposed. In this decomposition and recomposition no two equivalents which have been separated from each other are ever again reunited, but with military precision one set of like equivalents march one step

toward one pole whilst the other set march one step toward the other pole. Where these two opposite equivalents come together they unite and form a new atom, only to be again decomposed, and taking up their line of march the next opposite equivalents are reunited, and so on as long as the current continues to flow. In this onward march of equivalents at each step at either pole is liberated one equivalent, and thus there is an accumulation of like equivalents at either pole.

For instance, in the decomposition of water, oxygen accumulates at the positive pole or unites with the substance of which the electrode is composed, which if of metal becomes an oxide; whilst the hydrogen accumulates at the negative pole, and since it does not unite with this electrode it constantly increases in quantity.

When the electric current traverses animal tissue there is a double decomposition. All animal tissue is pervaded by a solution of chloride of sodium, and this as well as the water which holds it in solution is decomposed, the chlorine arriving with the oxygen at the positive pole, whilst the soda and the hydrogen arrive at the negative pole.

Other decompositions take place wherever other salts are traversed by the electric current, and as a

rule acids appear at the positive whilst the bases appear at the negative poles.

With this explanation of electrolysis we are prepared to understand Althaus' description of the results of experiments made by him during the years 1866 and 1867, where the changes produced by the electric current were observed by the aid of the microscope.

He says: "I have studied the action of the current upon the intimate structure of the skin and cellular tissue, muscular fibres and tendons, cartilages and bones, liver and pancreas, spleen and thyroid body, kidneys and suprarenal capsules, testicles, breasts and ovaries. The general result of these investigations has been that *no animal tissue whatsoever can withstand the disintegrating effect of the negative pole, and that the force and rapidity with which this disintegration is brought about are perfectly proportional to the motive force which is employed, and to the softness and vascularity of the structure acted upon.* Thus ten cells of a battery have a more thorough and rapid effect than five, fifteen more than ten, and so on; while, as regards the tissues, those containing most water, such as the muscles, the cellular tissue, the spleen, etc., are more rapidly disintegrated than those which con-

tain less fluid. Bones and teeth withstand the action of the current for a considerable time.

"A curious and novel circumstance forced itself early on my attention, and this was, that the electrolytic effect of the negative pole on animal tissues was mainly composed of two different elements, viz., of the mechanical action of the nascent hydrogen, which was, under the microscope, seen to rise in innumerable bubbles as soon as the circuit was closed, and to force itself, as it were, between the structural elements of the tissues, driving their fibres mechanically asunder; and, secondly, of the chemical action of the alkalies, soda, potash, and lime, which, together with hydrogen, are developed at the negative pole of the battery."—Pages 39, 40.

"It was then observed that needles connected with the negative pole of the battery could be inserted into, and removed from, the body without causing any loss of blood; that the current used did not appear to give much pain to the animal beyond what was due to the introduction of the needles to the skin; and that the parts operated upon shrank sensibly after the operation, but that there was neither inflammation, suppuration, nor sloughing. If the current was made to act upon bloodvessels, it was found that they were filled with

a foreign body, due to disintegration of the blood, and around which afterward a slow deposition of lamellated fibrin took place; they were thus changed into solid strings wherever the current had been made to act. It appeared fair to conclude from these observations, that the current could be safely and successfully applied to such parts of the body where shrinking and disintegration of tissue and obliterations of bloodvessels might be required for surgical purposes.

"The sores which are produced in the skin by the negative pole resemble those caused by caustic potash: and the same may be said of the cicatrices, for these latter have *no tendency to contract, but are soft and become gradually similar to the surrounding skin*, so that after some time no scar is perceptible, unless the action was originally very prolonged and very powerful."—Pages 41, 42.

In producing electrolysis, it is not necessary to introduce into the tissue to be destroyed any needles except those in connection with the negative pole, for, as is seen by the above experiments, no tissue can withstand the destructive effect of the negative pole. The positive pole may be a moist sponge applied to any indifferent part of the body; generally in the near vicinity. By the negative pole no

foreign substance is introduced into the tissues, and we need fear no medication therefrom, since the electrode is not acted upon chemically. But, "the immediate effect of the electrolytic decomposition of any animal liquid is, that the anode (or positive pole) is oxidized and chlorinated, and from a metal changed into a metallic salt, since no metal can resist the effects of oxygen and chlorine in their nascent condition." By introducing needles in connection with the positive pole into animal tissues "we may introduce into them salts of iron, copper, silver, gold, or any other metals used as directors, and which combine with the albumen to form albuminates."—Pages 42, 43.

In this description the effect of the negative pole is given where there is an independent battery in the circuit and the galvanic current is caused by chemical decomposition in this battery. The effect as described is at the electrodes. Our attention is called at this point to the difference between the direction of the current in and out of the battery. In the battery the current is from the zinc to the copper, and the oxygen goes from the copper to the zinc (by electrolysis), whilst the hydrogen travels toward the copper. Out of the battery the current goes from the copper to the zinc, and the oxygen of

any electrolyzed fluid goes to the pole in connection with the copper, whilst the hydrogen goes to that in connection with the zinc; as we see, the action is reversed. Now suppose, as is often the case, that we have an apparatus whereby animal tissue takes the place of the liquid in the battery. For instance, we take a plate of copper and a plate of zinc, and unite them by a copper wire. This we apply, perhaps, to the skin of a living person. We have in this arrangement a new battery, wherein the animal body with its fluids takes the place of the liquid in the ordinary battery. As soon as the application is made, chemical action takes place, and the solution of the chloride of sodium in the animal tissues is decomposed, the chlorine and oxygen going to the zinc plate, where composition immediately takes place, and we have formed the chloride of zinc. This is a violent escharotic and will destroy any moist animal tissue. Even so simple an apparatus as Garrett's disk will invariably create sores when left on the skin for a sufficient time.

In the electrolytic destruction of tissue the volume of electeicity is necessarily considerable, and to be successful it ought to flow through the conductors as freely as practicable. In electrolysis the action takes place *between* the electrodes, and not

on the conducting wires. In galvano-cautery the action takes place on or outside of a continuous conductor. In the one the effect is from the passage of the current through the tissue itself; in the other the effect is produced by the passage of the current through the conductor, and this by producing an elevation of temperature. When a large quantity of electricity is made to flow through a fine platinum wire it is soon heated even to whiteness.

A battery which is adapted to produce electrolysis would be of no use for a galvanic cautery, and *vice versa.* A battery adapted to produce the large quantity with small intensity required for galvano-cautery would be of no use in electrolysis.

In heating the fine platinum wire for the removal of tissue or growths, care must be taken not to produce too intense a heat, for a white heat cuts through so quickly that the bloodvessels are apt to be left open, and hæmorrhage is liable to be the consequence. Where the heat is too little, the operation cannot be performed. When the heat is properly adjusted, any tissue is quickly removed without liability to hæmorrhage, and the surface is not left painful, because the exposed ends of the nerves are for a certain distance destroyed, thus

preserving the sensitive parts from the irritating effects of the atmosphere.

No animal tissue can withstand the destructive effect of the galvano-cautery any more than that of the negative pole in electrolysis; yet the process is different. The tissue is destroyed by the galvano-cautery through the intense heat, and by electrolysis through chemical destruction.

Leaving this short sketch of the destructive effects of electricity, we pass to an investigation of the restorative effects of this wonderful agent.

"One great effect of electricity is its power to evoke function in all living tissue." (Poore.)

Function is the normal action of an organ or tissue. The function of an organ or tissue is active in proportion to the number of nerves distributed to this organ or tissue. A tissue to which few or no nerves are distributed has no independent function. For instance, the bones have no function proper; they are simply the framework which supports the other tissues that make up the completed organisms. Without the muscular system the bones would be an inert mass, with no power of locomotion. The function of the muscles is to contract, and if we combine the bones and muscles properly we have an approach to an organism.

Yet it is incomplete. If we add the nervous system, we then have all the parts necessary to complete locomotion. All the other organs are only necessary to give to the organism continued existence. *The nervous system constitutes the individual.* It is by and through the nervous system that all the functions of the different parts of the organism are evoked: and in order to realize how electricity has the power to evoke these functions, we must understand what the nervous system is (anatomy) and what it does (physiology).

The nervous system is composed of two kinds of matter, and these have entirely different functions. One kind is composed of cells, and these generate a force peculiar to itself. This force is the moving power of the whole system. The other kind of matter is composed of fibres, and these convey the force to its destination.

In order to impress the mind with the peculiarities of the nervous system we can do no better than to compare it with the batteries and wires of a telegraph company. Indeed, the cells are simply the nervous batteries, and the fibres are conductors. Familiarity with telegraphing makes it easy to study the nervous system by the help of this comparison. In telegraphing there is a head office

from which all orders are issued, and to which all intelligence is returned. In the nervous system the hemispheres generate the will-power, and from them are sent intelligent orders, and intelligence of what is going on is telegraphed back to these ganglia. In telegraphing there are as many different stations as there are places of doing business, and at each station are a greater or less number of batteries, according as the necessary business requires. In the nervous system are collections of cells whenever necessity requires to generate independent force for special purposes, and these collections are called ganglia. They correspond to different stations in telegraphy. Each station is connected with the other stations and with the head office by conductors. All the ganglia are connected with each other by connecting fibres. In the telegraphic head office are the president, directors, and secretary. The hemispheres preside over the ganglia, and here are the records kept. The second office of importance in telegraphy is that of the superintendent. It is here that all messages of a general character relating to the business of the company are received. All orders from the head office are here re-telegraphed. Corresponding to the superintendent's office is the

ganglion or ganglia of the pons varolii or tuber annulare, and it is here that all messages of sensation are received, and from these ganglia all motor messages are sent. The function of these ganglia is to superintend the business of the nervous system. All along the spine are important ganglia where nervous force is generated, and conductors take their origin in them.

There is one difference between the conductors of nervous force and those of the telegraph company. Nervous fibres conduct only one way. Telegraphic conductors conduct both ways. In all spinal nerves there are two sets of these fibres. One set conveying messages from the exterior to the centres, and the other conveying messages out from the centres. These are the sensory and the motor fibres. These two sets of fibres, although gathered together in the same nerve, are completely insulated from each other, and no outward-bound message ever interferes with an inward-bound one. But this fact of the two sets of conductors, the centrifugal and the centripetal, being always found together in the spinal nerves, must be taken into account where electricity is used in living animal tissue. The functions of each set of fibres is to convey messages in its own particular direction, and

since a current of electricity evokes function, it follows that a current sent toward the periphery will evoke muscular contraction; while a current sent toward the centre will give the impression of pain.

We should endeavor to understand what is meant by "reflex action" as applied to the nervous system. This is, perhaps, best taught by an illustration; for instance, the secretion by the submaxillary gland. It requires three sets of nerve fibres in order that this gland shall perform its function and saliva be secreted. First, the chorda tympani, or gustatory portion of the trifacial, which is a branch from the seventh cranial nerve, is centripetal, and conveys messages to the central ganglia. But we find, on further examination, that it is not purely centripetal, for we find, on section of this nerve, that irritation applied to either end will cause a flow of saliva from the submaxillary gland. It would be very easy to understand the action of this nerve, provided that irritation of only one cut end of the nerve produced function; for if merely the end, in connection with the gland, produced function, we should infer that this nerve was simply a mixed nerve, and that it transmitted both ways; and, further, that all the centrifugal fibres of the submaxillary gland were in this nerve. But, since

irritation of both cut ends produce function, we see that there must be some other nerve containing centrifugal fibres distributed to the submaxillary gland. The origin of the seventh nerve is in the floor of the fourth ventricle, and it is to this vicinity that information is sent that saliva is needed. Somewhere in this vicinity is the origin or the situation of the ganglia from which arises the vasomotor nerves. Filaments of these nerves are distributed over the entire organism, and principally follow the arteries. The function of the vasomotor is to keep the arteries in a constant state of partial contraction, greater or lesser, according to the needs of the part; while dilatation of the arteries is effected by cerebro-spinal nerves, which act upon the vaso-motor centres to cause them to relax the contraction of the arteries. When, for instance, saliva is needed, the gustatory nerve telegraphs to the centre this necessity of secretion; this intelligence is reflected upon the vasomotor centre, and more or less paralyzing impulse is sent through its fibres to the arteries of the submaxillary gland, i. e., the function of the vasomotor (which belongs to the sympathetic*), is lessened, and the arteries enlarge. More blood goes to the gland, and more saliva is

*Bernard, Kuss, Legros.

therefore secreted. When the excitation (presence of food) of the centripetal nerves ceases, the sympathetic resumes its function, and the arteries contract and shut off the extra flow of blood to the gland; but irritation of the peripheral end of the cut nerve also produces an increase of saliva; this is probably to be explained by the paralyzing action of the fibres which go to the submaxillary sympathetic ganglion, for this ganglion has an intimate connection with the submaxillary gland. The impulse probably paralyzes the vasomotors going from the ganglia to the gland. All the functions of the organism are regulated in this same way. The nervous system is more or less directly a system of checks and balances. Each nerve has its antagonist, and in health these are evenly balanced, and the action of each checks that of the other.

The study of the all-pervading function of reflex action forms a large part of electro-physiology. Seguin defines a reflex action as a transformation by nerve-cells of a sensitive impression (with or without consciousness) into motion, chemical action, or ideas. The parts essential to the performance of a reflex action consist of a centrifugal (sensory) nerve to transmit the excitation, ganglionic cell to transform the impulse, and a centripetal nerve to

carry this impulse to the muscle, gland, or cerebral convolutions. The results of the activity of such an apparatus are, motion (common, muscular, or vascular), secretion, ideation. From this definition one can readily imagine that reflex actions occur in nearly every part of the body, in small segments of it as well as in large portions. A heart excised from certain animals will continue to beat for some time in response to irritation. Contraction may be obtained by irritating a small portion of intestine removed from the body; and a small segment of the spinal cord will suffice to give reflex movements to the muscles supplied by that piece of cord. Reflex action takes place in all parts of the nervous system (spinal axis, cerebrum, sympthetic system,) and at all times; and it is through this kind of action that the most importent bodily functions (including cerebration, in part, certainly,) are produced. There is a tendency to consider all active nervous phenomena of a reflex nature, denying the existence of spontaneity in the animal frame; and we must admit that a good deal can be said in support of this extreme view.

A full understanding of reflex action seems necessary to a complete appreciation of electro-physiology.

Function is evoked in the submaxillary gland by

passing a current of electricity through the tongue, or if we experiment on animals and expose the chorda tympani, we pass a current through this nerve. By this means a sense of gustation is conveyed to the centre, and from this centre through the vasomotor nerves is transmitted paralyzing or dilating impulse to the arteries supplying the submaxillary gland. This is the most certain way to start secretion in the gland by electricity.

The direct antagonism of certain nerves to each other, is clearly illustrated by the action of the nerves distributed to the heart. Experiments have been so often made, and by so many different observers, with the same result, that there can be no doubt of the truth of the conclusion arrived at. The heart is supplied with nerves from two sources, viz., the sympathetic and the pneumogastric. Electrization of the sympathetic increases the pulsations of this organ, whilst electrical irritation of the pneumogastric slows and finally arrests these pulsations. Thus we find that the sympathetic nerve is the motor nerve* of the heart, and the pneumogastric

*The brothers Cyon, of St. Petersburg, proved that the branches of the inferior cervical ganglion terminate in the ganglion of the heart, that they are accelerators of the heart's action, and therefore antagonist to the pneumogastric. *Journal of Hom. Clinics*, vol. i, page 11.

the inhibitory nerve. At its origin the vagus is purely a centripetal nerve, and conveys messages by its own proper fibres only toward the centre. The spinal accessory, whose origin is in the immediate vicinity of the pneumogastric, is purely a centrifugal nerve, and conveys messages only from the centres. Near the origin of this nerve a branch joins the pneumogastric and follows it as far as the heart, to which it is distributed. It is this centrifugal branch which constitutes the inhibitory nerve of this important organ.

As we have seen, the motor nerve of the heart is the sympathetic, and when the action of this nerve is not antagonized by the inhibitory nerve, as when the vagus is paralyzed, we have rapidly increased pulsations, which are proportioned to the degree of paralysis. When there is loss of power in the sympathetic we find the number and force of the pulsations lessened.

The superior laryngeal or second branch of the pneumogastric is a sensory nerve. Of very great importance is a branch from this nerve which joins a branch coming directly from the pneumogastric. By the union of these two is formed what is called the depressor nerve of the circulation; this is a centripetal or sensor nerve telegraphing from the

heart to the centre. When this nerve is divided, electrical irritation applied to the end in connection with the heart produces no results; applied to the end in connection with the centre it reduces the pressure in the arteries, diminishes little by little until it may be but to one-half or two-thirds of the normal pressure.

A peculiarity of all nerves is, that irritation applied anywhere in their length is manifested at their distribution. Irritation applied to a motor nerve produces contraction of the muscles. Irritation applied to a sensory nerve is manifested by sensation at its distribution. Electricity applied to the pulmonary branch of the pneumogastric (sensory) causes titillation in the bronchial mucous membrane, and by reflex this produces cough, sometimes of great violence.

One very important lesson may be learned from the application of an electric current to that part of the pneumogastric nerve going to the heart, viz., that a current of sufficient strength to arrest the pulsations soon paralyzes the nerve, and when this is complete the heart commences its pulsations again. This paralyzed condition of the nerve is called an electrotonus, and this condition is always produced when a current of sufficient strength is passed through a nerve.

The effect of the electric current at the two poles is not the same. At the positive pole is produced a benumbing effect or a lessening of nerve irritability. These conditions affect that portion of the nerve which is included between the poles as well as to a certain extent outside of them. A portion of the nerve in proximity to the positive pole partakes of the lessened irritability, and that part in proximity to the negative pole partakes of the increased irritability. A neutral point separates the two. This point is determined by the strength of the current. With a weak current there is very little or no benumbing or lessening of nerve irritability; the entire included portion is in a condition of exalted irritability and conducts more readily than in its natural state. This is called catelectrotonus. With a medium strength of current this neutral point may be midway between the points touched by the poles of the battery, and in this condition the nerve conductivity may be unchanged from its natural state, since what is lost by the lessening effect of the positive pole is made up by the increased activity of that portion in the vicinity of the negative pole. With a very strong current the benumbing effect of the positive pole includes the whole portion of nerve between the poles of the

battery. In this state the conductivity of the nerve is arrested or nearly so, and its function is suspended.

In the therapeutical use of electricity this difference of effect at the two poles decides us in our choice of strong or weak currents. With a strong current we lessen function, with a weak one we exalt function. This readily explains why the heart resumes its pulsations when its inhibitory nerve takes on the state of an electrotonus, since in this condition the nerve cannot convey the force from the centre even, and has lost the increased functional activity which it at first received from the application of electricity. The sympathetic nerve remains intact, and reproduces the pulsation.

Although all kinds of electricity to some extent produce electrotonus, yet no reliable use can be made of any of the varieties for this purpose except the galvanic current. So unreliable are all other forms that we may assume that the galvanic current is the only one which will produce this effect, and do it always.

The question naturally arises, How does electricity produce its effect? It is not easy to answer this question further than to say, by a process resembling catalysis.

In chemistry, catalysis is the production of a decomposition, and following this is a recomposition of elements in some other form, by the presence of some other substance than those acting upon each other, and which substance does not enter into the chemical compound. This readily explains the effect of electrolysis, but not the manner in which the function is evoked. All the vital processes, viz., digestion, nutrition, absorption, secretion, etc., are carried on by the aid of catalysis, and in all probability electricity is the force by which they are to a great extent guided.

The restorative effect of electricity! How shall we describe it?

"Remak's *catalytic* effects of the constant current are those which are produced by direct stimulation of the vasomotor nerves, which latter transmit the influence to the bloodvessels and lymphatics. In this way the process of nutrition throughout the system may be influenced by galvanization. It appears to us that for *catalysis* we might substitute this more intelligible term, *catelectrotonus.* By catelectrotonus of the vasomotor nerves absorption is promoted, and effusions may be thus removed into the general circulation. Most probably the therapeutical effects of the current in rheumatism and

in rheumatic gout, in dropsy of the joints, etc., are owing to what may be called *catalysis;* or, better, *catelectrotonus of the vaso-motor system of nerves.*"

A current, not of sufficient strength to destroy living tissue, "starts a process that continues long after the current ceases to flow. The average ultimate effect is to increase the flow of blood, raise the temperature, and dilate the veins." (Beard and Rockwell.)

A current of electricity flowing through any liquid causes motion in this liquid, and this motion is from the positive toward the negative. Through experiment it has been found that by the use of the constant current, liquids can be made to pass through a porous diaphragm, and by the same agent fluids are made to change place in living tissue. Solids may be broken up and moved in the same manner, and by the general circulation thus removed and ultimately discharged by the emunctories.

It is the united testimony of electro-therapeutists that the weak current of galvanism is the curative one, and that when the harm comes from its use too strong a current has been used. I give a few extracts showing the view held in this respect:

"*It may be laid down as a general principle that a feeble current used for a short time produces the*

greatest therapeutical effects. A very powerful current almost always does harm instead of good, and more especially where it is applied for a considerable length of time." (Althaus, p. 329.)

"Benedict has justly laid stress upon the necessity of *short* applications (never more than half a minute). Meyer recommends an application of two or three minutes' duration; but this is for most cases too long. I am in the habit of employing the current from thirty to ninety seconds at a time. The result of the first or second application generally gives the clue as to what length of time the application should last; if the shortest time seems to answer it is not necessary to try a longer one, as sometimes the benefit already obtained is thereby counterbalanced." (Althaus, p. 331.)

"We do not usually observe any sensible contraction of muscles when under the *steady* running of a *feeble* current of galvanism. But this, as say Remak, De la Rive, and others, does not prove that there is not a certain effect being produced on the nerves by the steady and gentle inworkings of this current. Indeed, here, according to my experience, is one of the most marvellous and valuable effects of all the medical uses of electricity." (Garratt, p. 175.)

In the foregoing description of the induced current and the apparatus it refers to the most simple and perhaps we may say, primitive machines. These were they with which we were obliged to do our work when we commenced twenty and thirty years ago. During a few years past great improvements have been made which enables us to do our work easier and with a great deal more satisfaction. From appearances I judge that all the modern instruments are intended to work nearly alike. The induction machine which I use, and the only reliable one I have, is from the factory of Mr. Otto Flemming. It is the most beautifully-finished instrument I have seen. All the exposed metal is heavily nickle-plated and shines like a mirror. The conductors are kept in a drawer especially for them, and all that is necessary is to pull out the drawer and lift the conductors out and apply the poles where necessary. In order to accomplish this there is a most ingenious arrangement by which the extra current, the secondary current, and the negative pole can be commanded at pleasure. This is accomplished by three switches which are easy of access on the top of the machine proper. It will be remembered that the coil which supplies the extra or primary current is independent and perfectly

insulated from that which gives the secondary current. By the position of the switch either current is turned on the conductors. The letters P and S indicating the direction which the switch must take to accomplish this. Another switch regulates the strength of the current which it is necessary to use. There are four degrees of power to each current, and this is regulated by turning the switch so as to touch either of the four buttons with which it is connected. One switch is designated by P (primary) and the other by S (secondary). In addition to these the power may be increased by withdrawing the shield which separates the different coils. With these the power of the current may be regulated to a nicety.

It will be recollected that the induced current is but slightly manifested at the positive pole and we rely only for remedial purposes on the negative. Another switch determines to which conductor the negative must apply. Another thing that is of prime importance, and I find almost indispensable, and that is the absolute safety with which the machine can be transported without injury from the fluid. This is so absolutely corked up that, in my instrument at least, not a drop of fluid escapes. Again, there is no chance for the fluid (which is very

destructive) to get upon any metal. It is corked up as securely as though in a bottle. Any one who has been in the habit of carrying his battery about has encountered the difficulty of protecting the metallic connection and of keeping the fluid in place. The lever for slow interruptions does its work well, but when very lengthened interruptions are wanted the handle for this special purpose is best, for by it the interval can be made as long or short as seems necessary. This is a very important thing in testing the muscles either to ascertain their excitability or for applications for paralysis. What is said about Flemming's induced-current batteries, of which he offers several different sizes, must be equally acknowledged to be true in regard to his continuous galvanic current batteries; they are very effective, substantial and handsome in their construction.

Errata.—On title page, for Electro-*Therapeutics* read Electro-*Physiology.*

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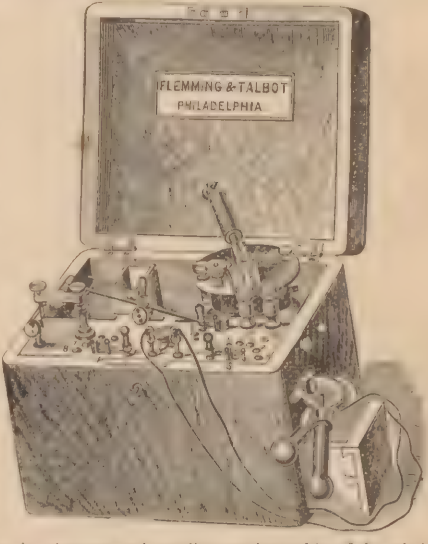

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